JOURNAL OF PHYSICAL AND CHEMICAL SCIENCES

Journal homepage: http://scienceq.org/Journals/JPCS.php

Research Article Open Access

Assessment of The Use of Energy Saving Bulbs and Analysis of Their Luminous Efficiency: The Case EEPCO Customers in Wolaita and Dawro zones of SNNPR

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Received: July 21, 2017, Accepted: August 26, 2017, Published: August 26, 2017.

ABSTRACT

Electrical energy demand in Ethiopia has been enormous in past years as a result of economic growth and development. Hence, more efficient use of energy must be considered as one major option to achieve sustainable developments. The goal was to assess the degree to which energy-saving bulbs(CFLs) are being used in target area and to determine luminous efficiency of bulbs used by customers. Data was collected using questionnaire, interview and laboratory experimentation and analyzed using logistic regression, percentages and correlations. It was revealed that only 57% of customers included in the sample were users of energy saving bulbs and probability that a customer uses CFLs is significantly affected by monthly income and understanding towards energy saving strategies. Correlation coefficient between number of CFLs and monthly income was found to be R = 0.362. A customer with average monthly income and with understanding on how to save energy is 7.48 times more likely to use CFL than a customer with the same monthly income but with no understanding. It was found that average luminous efficiencies of CFLs and non-CFLs were 12.369% and 2.554% respectively. If all bulbs used wereCFLs, then 1335996 KWh per year could have been saved.

Keywords: *Correlation, Luminous Efficiency, Logistic Regression, Odds-Ratio.*

INTRODUCTION

In most developing countries electrifying rural households by extending the main grid is a major challenge due to economic and technical reasons [1]. Ethiopia has one of the lowest rates of access to modern energy services; its energy supply is primarily based on biomass. With a share of 92.4% of Ethiopia's energy supply, waste and biomass are the country's primary energy sources, followed by oil (6.7%) and hydropower (0.9%). Furthermore, 99% of households, 70% of industries and 94% of service enterprises use biomass as energy source.Households account for 88% of total energy consumption, industry 4%, transport 3% and services and others 5%. The installed electricity generating capacity in Ethiopia is about 2060 MW (88% hydro, 11% diesel and 1% thermal) and production covers only about 10% of national energy demands. (Zelalem et al., 2013)

According to the Ethiopian Electric Power Utility, only an estimated 41% of the Ethiopian population has access to electricity from the national grid (people living in the proximity of electric grid). The actual connected house hold is not more than 10%.With almost 85% of the Ethiopians living in rural areas, there is a significant bias between the power supply of urban and rural population; only 2% of the rural but 86% of the urban residents have access toelectricity. Percentage of population receiving electricity in rural area is less than 1% of the total population. The Ethiopian government attempted to reach rural areas through grid extension or diesel generator by subsidizing rural electrification programs. In most cases, these projects have failed to reach the targeted customers [6]. It is, thus evident that alternative approaches to rural electrification schemes have to be found.

In theory, energy efficiency is an inexpensive win-win proposition, particularly when supply capacity is severely constrained, as it is in many African countries [5]. While end users can reduce their energy spending, power utilities can avoid costly new investment in developing their capacity. At the same time, manufacturers and vendors of energy-efficient technology can profit from the sale of energy goods or services. Moreover, energy efficiency can contribute to mitigating the effects of global warming. Africa is not a major CO2 emitter at present; the region only accounts for some 3 percent of total CO2 emissions, while about 15 percent of the world's total population resides there. However, among other developing regions, Africa is projected to be among the most vulnerable to climate change and possible extreme events [5].

Recently, Ethiopia carried out a series of CFL bulb distribution programs. On the first phase of these programs, 350,000 compact fluorescent lamp bulbs were distributed free of charge. The impact related to this first phase is estimated at about 45 to 50 kilowatt hours per customer per month, or about 13.3 megawatts of energy savings in total. The overall impact of the compact fluorescent lamp bulb programs, to which more than 5 million bulbs were distributed, could be significantly larger. However, about 20 percent of the initial energy savings disappeared within 18 months of the program's completion [5]. On the other hand, the electrical energy demand increase in Ethiopia has been enormous in the past few years as a result of economic growth and development. This increase is expected to continue in the years to come. Hence, more efficient use of energy has to be considered as one of the major options to achieve a sustainable development [3].

1.1 General overview of the study area.

The target areas for this investigation are Wolaita&Dawro Zones of South Nations, Nationalities and Peoples Region (SNNPR) in Ethiopia. Wolaita Zone is organized in 12 woredas and 3 city administrations (Sodo, Areka and Boditi) while Dawro Zone is

organized in 5 woredas and 1 city administration (Tercha). Moreover, according to Ethiopian Electric Power Utility, the study area is sub-divided in to 3 districts in Wolaita Zone (Sodo, Boditi and Gesuba) and one district in Dawro Zone (Tercha).
Wolaita Zone lies between 6o54'N and 37o45'E with elevation ranging from 1600 to 2100 meters above sea level. It is located at about 330km south west of Addis Ababa, 160km from Hawassa and has a total area of 4471.3 km2. Dawro Zone lies between 7.0000oN and 37.1667o E with elevation ranging from 501 to 3000 meters above sea level. It is located at about 313 km south west of Addis Ababa, 265 km from Hawassa and has a total area of 4814.52km2.

MATERIALS AND METHODS

Materials.

One major component of the study has been experimental verification of the luminous efficiencies of the bulbs which were randomly taken from the market. To perform this task, materials such as digital multi-meter, heat sensor, lux meter, ruler, bulbs of different brands and other related devices were used.

Methods

This study is based on an assessment of existing practices of the uses of energy saving bulbs (CFLs) by the customers in the study area. Areka, Gesuba and Gesachire districts were the subjects of the study.To measure the luminous efficiency of sample bulbs used by the customers, experimentswere conducted using digital multi-meter, heat sensors, lux meter and ruler.Additional information useful for the study was also collected from officials of the aforementioned districts.
Cluster sampling was used with each Woreda and city administration in Wolaita and Dawro Zones being treated as a cluster. Simple random sampling (SRS) was applied to select the clusters and the subjects of the research in each cluster for the research.
For any sample design, deciding upon the appropriate sample size depends on five key factors namely, margin of error (precision), variability in the population, confidence level, the population proportion and the population size [2]. The total sample size (m) was determined by the formula: m =(〖 〖(Z〗 ^2〗 _(α/2))(0.25))/E^2 where α is the level of significance and E is the margin of error set by the investigators. For this research, investigators have chosen α = 0.05 and E = 0.02. The sample size in a cluster was determined by the formula ni=(Ni/N) *m where N is the total number of households in the target clusters and Ni is the number of households in that cluster and ni is the number of sample customers in that cluster.
Questionnaire surveys were used to collect data from sample customers. To check the validity of the data that was collected through the questionnaire, some of the respondents who participated in the questionnaire survey were also interviewed.
The required software, the SPSS version 21 that is anticipated to support the study has been utilized. After collecting all the required data from sample customers and experimentation, the data were arranged, reorganized and analysed. Binary logistic regression was used to analyse the data collected from customers. The number of CFLs and incandescent bulbs were correlated with the monthly income of the target customers to see the strength of the association between them.The probabilities that a customer with a given monthly income and understanding on how to save energy will use CFLs were also calculated.
To determine the luminous efficiency of different brand bulbs collected from the market (coded as 01 to 10) the researchers conducted experiments using digital multi-meter, NTC heat sensor which reads 100mV/0C on output, Paroux2 Lux meter and ruler. The output power in the form of light was calculated by taking the difference in lux meter reading (in lumens) and the illumination value of the surrounding area (80 lumens on average) and then multiplying the result by the conversion factor 0.001496 to convert the unit into Watts.

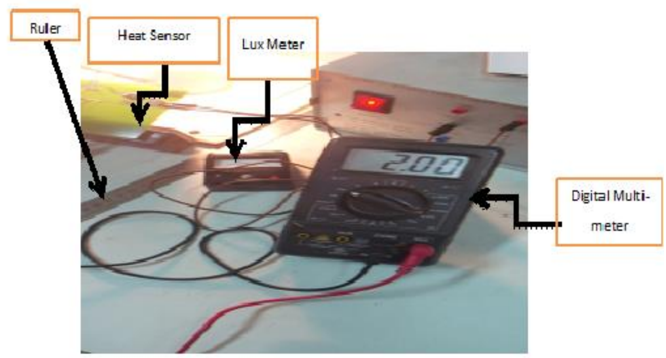

Figure1: Picture of the experimental setup for measuring the efficiencies of the bulbs.

The data collected through questionnaire was systematically rearranged and loaded into SPSS version 21. Binary logistic regression was applied to analyze the data and calculate the probabilities of using CFLs. Customers using 2 or more CFL, are considered as users of CFL and coded as 1 while others are coded as 0. Up to the time of data collection, EEPCO has distributed CFLs to its customers in two rounds. Moreover, two CFLs were sold to each customer in each round. A Customer is expected to buy a total of at least 2 CFLs in both rounds to be considered as a CFL user. The total amount of electric energy that could be saved by the 600 sample customers was calculated by taking the difference between the electricity consumption for the existing mixture of bulbs and the electricity consumption if all bulbs were CFL.

RESULT AND DISCUSSION

3.1 Analysis of the data collected by questionnaire.

The data collected via questionnaire was organized and the following results were obtained. The average number of lighting hours per day used by sampled customers was calculated to be 4.779 hours.

Table 1: The result of energy/money savings from sample customers.

	No of customers	No of Incande-nscents (commonly 60W)	Average no of Incande-nscents (commonly 60W)	No of CFL	Average no of CFL (commonly 15W)	Total energy consumed for existing mixture of bulbs (KWhr)	Total energy saved if all bulbs were CFL (KWhr)	Total money paid with existing mixture of bulbs (Birr)	Total money saved if all bulbs were CFL (Birr)
Sample	600	3200	5.33	1564	2.61	30118.5	22499.1	8870.115	6789.79
Population	2969	15835	5.33	7739	2.61	149036.2	111333.0	43892.3	33598.2

As can be observed from table 1, if all bulbs were CFL, 22499.1 KWh of energy could have been saved from sample customers and 111333 KWh of energy from all customers in Wolaita and Dawro Zones per month or 1335996 KWh per year. This is a very large amount of energy saving which could have been used for other development activities. On the other hand, a customer could have saved 11.32 Birr per month or 135.8 Birr per year on average if all bulbs used were CFL.

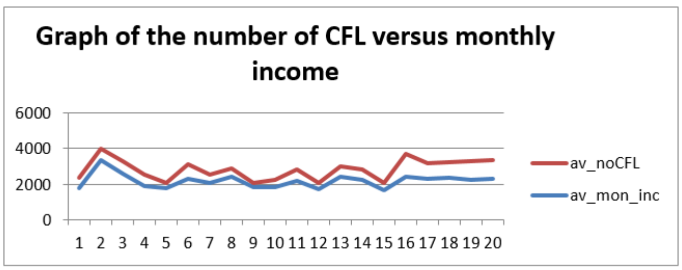

Figure 2: Graph of number of CFL versus monthly income

The above figure was obtained by grouping the data 30 in one, taking the average of each group and then multiplying the data for number of CFL by 250 to make the scales approximately the same so as to make the plot appear clear. From the plot, we can see that the use of CFL increases with monthly income. This is also verified by the correlation coefficient between the number of CFL and monthly income which is R = 0.362.

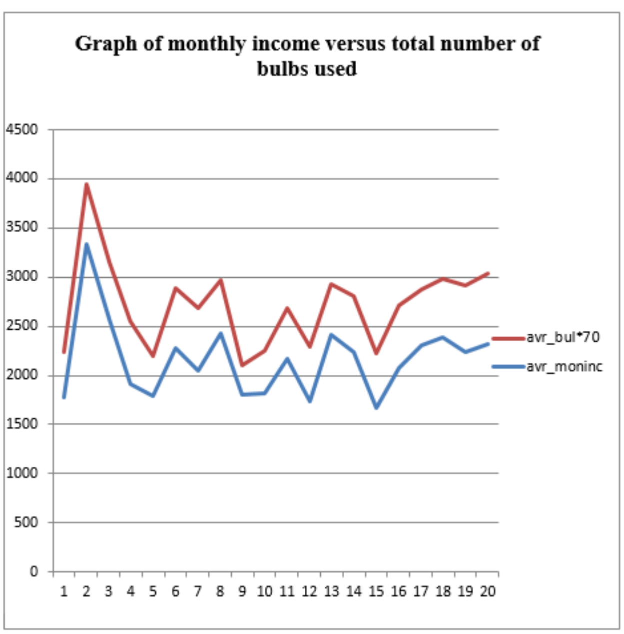

Figure 3: *Graph of the total number of bulbs used versus monthly income of a customer*

The correlation coefficient between the total number of bulbs used and monthly income is R = 0.206. This is less than the correlation coefficient between the number of CFL and monthly income which implies that whatever the monthly income is, a customer must buy a bulb to light his home. But monthly income plays a significant role in determining the number of CFL used.

3.2 Interpretation of the output of the logistic regression model.

3.2.1 Determination of probabilities of using CFL.

In using Logistic Regression model, it is assumed that homogeneity of variance and normality of errors need not beconsidered, but it requires absence of multi-collinearity, no specification of errors (all relevant predictors are included and irrelevant predictors are excluded) and larger sample size is required than using linear regression. Furthermore, non-linear relationship is assumed between predictors and binary outcome with the regression coefficients being estimated using maximum likelihood approach[4]. To this end, the researchers used large sample size, particularly 600 samples.Only 342 customers (57 % of customers in the sample) are CFL users. Because of randomness during sampling, the sample proportion can be unbiased estimator of the population proportion. The remaining 43 % (1277 customers) are non-users of CFL. This indicates that awareness creation programs must be applied especially for customers with low monthly income.

The likelihood ratio tests check the contribution of each effect to the mode and -2Log likelihood ratio test indicates whether a set of independent variables improves prediction of dependent variable better than chance. Only monthly income and understanding level make significant contributions to the model used or to the prediction of the number of CFL. The ultimate goal of logistic regression is to determine the probability of a case belonging to the 1 category of dependent variable or the probability of event occurring (event occurring is always coded as 1) for a given set of predictors[4].

We see from table 3 that only monthly income and understanding on how to save energy using CFLs are significant contributors to the use of CFL (p-values less than 0.05). That is to say, at 0.05 level of significance, work type and education level of a customer do not contribute to use of CFL.

Table 2: The output of multinomial logistic regression taking all variables into the model.

Likelihood Ratio Tests				
Effect	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	348.206[a]	.000	0	.
W_type	357.048	8.842	4	.065
EducLevel	351.249	3.043	3	.385
Mon_Inc	556.743	208.537	87	.000
Understand	370.862	22.657	1	.000

Table 3: The output of binary logistic regression taking understanding and monthly income as significant predictors of the use of CFL.
Variables in the Equation

	B	*SE*	*Wald*	*df*	*Sig.*	*Exp(B)*
Mon_inc	.001	.000	45.595	1	.000	1.001
Step 1[a] Understand	2.014	0.557	13.068	1	.000	7.493
Constant	-2.804	0.569	24.274	1	.000	.061

The Wald test indicates the effect of individual predictor while controlling other predictors and the Exp(B) part indicates the likelihood of occurrence of one variable as compared to another variable [4]. It is evident from the table that keeping monthly income constant, a customer with understanding on how to save energy using CFL is 7.493 times more likely to use CFL bulbs.

Using these variables as significant predictors, the probability of using CFL is calculated as follows.

$$p = \frac{1}{1 + \exp(-(const + {}^{\beta}1 * x1 + {}^{\beta}2 * x2 + \cdots))}$$

Where x_1, x_2, x_3, … are predictor variables and $^{\beta}{}_1$,+$^{\beta}{}_2$, $^{\beta}{}_3$, . . . are the corresponding coefficients. Using the results from table3 and with replacement of the independent variables x_1 and x_2 by monthly income and the understanding of customers, we will have the formula

$$p = \frac{1}{1 + \exp(-(const = -2.804) + 0.001 * mon\_inc + 2.014 * understand}$$

Table 4: The probabilities that a customer will use CFL having monthly income of minimum (Birr 208), average (Birr 2198) and maximum (Birr 8000).

Monthly income (Birr)	Understanding on how to save energy using CFL	Probability of using CFL
208	yes	0.358
	no	0.069
2198	yes	0.803
	no	0.353
8000	yes	0.999
	no	0.994

Given the monthly income and understanding level, one can calculate the probability that a customer will use CFL. The results from table 4 show that the probability that a customer will use CFL for minimum or average monthly income is highly dependent on the understanding of the customer on how to save energy using CFL while the probability that a customer will use CFL for maximum monthly income is not highly dependent on the understanding of the customer. As monthly income becomes more than the average, the probability of using CFL will be less dependent on the understanding level and as monthly income becomes less than the average, the probability of using CFL will be more dependent on the understanding level of the customer. This can be verified using the odds ratios and is a very interesting result. Therefore, we can suggest from the results in table 4 that awareness creation programs need to be applied especially for customers with monthly incomes less than the average value of Birr 2198.

Table 5: The HosmerLemeshow Test

Hosmer and Lemeshow Test		
Chi-square	df	Sig.
16.761	8	.055

This test assesses whether the predicted probabilities match the observed probabilities. To that end, $P > 0.05$ means a set of independent variables will accurately predict the actual probabilities. Indeed, the predicted probabilities match the observed probabilities since the value of p is greater than 0.05 ($P = 0.055$).

Table 6: The Nagelkerke R^2 Test, Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	712.534[a]	.164	.220
a. Estimation terminated at iteration number 5 because parameter estimates changed by less than .001.			

Pseudo R square (Nagelkerke R^2) is preferred to the Cox & Snell R Square since, in this case, the model accounts for almost 10% of variance of the dependent variable i.e the number of CFL used. Nagelkerke R^2 indicated that the model accounted for 22% of the total variance in the prediction of the probabilities of using CFLs. On the other hand, other variable not indicated here account for 78% of the variance in the prediction of the probabilities.

3.2.2 *Determination of the odds ratio.*

Odds of using CFL with average monthly income of 2198 Birr and with understanding on how to save energy =0.803/(1- 0.803) = 4.088 and odds of using CFL with average monthly income of 2198 Birr and without understanding on how to save energy =0.353/(1- 0.353) = 0.546. Therefore, the odds ratio will be = 4.088/0.546 = 7.48 which implies that customer with monthly income of 2198 Birr and with understanding on how to save energy is 7.48 times more likely to use CFL than a customer with monthly income of 2198 Birr having no understanding. This is also evident from table 4 above.

Odds of using CFL with average monthly income of Birr 8000 and with understanding on how to save energy =0.999/(1- 0.999) = 999 and odds of using CFL with average monthly income of Birr 8000 and without understanding on how to save energy =0.994/(1-0.994) = 165.67. Therefore, odds ratio will be = 999/165.67 = 6.03. That is, a customer with monthly income of Birr 8000 and with understanding on how to save energy is about 6.03 times more likely to use CFL than a customer with monthly income of Birr 8000 but with no understanding.

Odds of using CFL with a monthly income of Birr 208 and with understanding on how to save energy =0.358/(1- 0.358) = 0.558 and odds of using CFL with average monthly income of Birr 208 but without understanding on how to save energy =0.069/(1-0.069) = 0.074 and the odds ratio = 0.558/0.074 = 7.54. That is, a customer with monthly income of Birr 208 and with understanding on how to save energy is about 7.54 times more likely to use CFL than a customer with the same monthly income but with no understanding.

3.3 Analysis of the data collected through experimentation.

The bulbs of 5 different brands were coded 01 to 10 and the efficiencies of each bulb were calculated as depicted in table 7.

Table 7:The efficiencies of bulbs of different brands.

Bulb type	Brand Code	Bulb Code	Marked Wattage(	Calculated /input	Efficiency (%)
Non CFL	V	01	60	49.590	2.436
		02	60	50.281	2.672
CFL	W	03	15	6.498	15.448
		04	15	6.498	8.142
		05	15	8.624	17.936
		06	11	6.528	7.066
	X	07	15	8.664	9.238
		08	15	8.664	9.238
	Y	09	11	6.528	16.423
	Z	10	11	8.664	14.723

As we can see from table 5, there is a difference between the wattage of bulbs marked by their producers and the input wattages calculated using the experimental data. The reason for this could be due to less accurate experimental data or incorrect marking of the wattages of the bulbs by producers.

The efficiency of the non CFL bulbs was calculated to be 2.554% while the efficiency of CFL bulbs was calculated to be 12.369% on average. The CFL bulb with code 05 had the highest efficiency (17.936%) and the CFL bulb with code 06 had the smallest efficiency (7.066%). The efficiencies of bulbs with brand code W range from 7.066 % - 17.936% while the efficiency of bulbs with brand code V range from 2.436 % to 2.672 %. Bulbs with brand code X have the same efficiency. The ratio of the average efficiencies CFLs to the average efficiencies of the non CFLs was calculated to be 4.844. That is to say, the CFLs were found to be about 5 times more efficient than the non CFLs which is in agreement with result in the literature.

Among the CFLs tested, bulbs coded 05 and 09 were the most efficient bulbs and recommended for use by the customers.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions.

Based on the categorizing criteria we used, only 342 (57%) of the 600 sampled customers were CFL users. This clearly indicates that there should be professional interventions to educate the customers on how to save energy or money. Not only money that can be saved but the energy saving can also be employed for other economic activities without the need to have new grids.

Moreover, if all customers were using CFL, 22499.1 KWh of energy could have been saved from sample (600) customers and 111333 KWh of energy from all (2969) customers in Wolaita and Dawro Zones per month or 1335996 KWh per year. This is a huge amount of energy saving which could have been used for other development activities. On the other hand, a customer could have saved 11.32 Birr per month or 135.8 Birr per year on average if all of his/her bulbs were CFL.

The researchers found out a number of problems that are hampering the use of CFL which can be categorized in to input, skill and awareness-related issues. Some of the serious problems are Insufficient supply of CFLs by EEPCO as compared to the demand from its customers, outdated fuses and switches under use, insufficient number and qualification of field workers, three districts are sharing a single switch, lack of awareness, delay of answers for the request of electric meters, demand for old bulbs by EEPCO so as to sell new CFL bulbs to its customers, and high cost of CFLs as compared to incandescent bulbs especially for low income customers. The aforementioned problems must be solved in order to enhance the use of CFL bulbs which enable energy savings.

The researchers have found out that the efficiency of sampled incandescent bulbs has been calculated to be 2.554% and that of the sampled CFL bulbs has been calculated to be 12.369%. This clearly shows that CFL bulbs are about 5 times more efficient than the incandescent bulbs and this is in agreement with the theoretical values. Furthermore, CFL bulbs coded 05 and 09 were the most energy efficient while the code 06 was the least energy efficient. The researchers also observed a wattage difference between the values marked by producing enterprises and those experimentally determined. Moreover, unless tested experimentally, the wattage markings given by the producing companies cannot be trusted.

The respondents have pointed out that the life spans of compact fluorescent lamps that are obtained from the market are shorter than those supplied by EEPCO. Moreover, the prices are also by far greater than those sold by EEPCO.

At 0.05 level of significance, the probability of using CFL is found out to be dependent on the monthly income of a customer and his/her understanding on how to save energy using CFL. The level of education and work type were found less significant (at 0.05 level) in predicting the probability of using CFL. Moreover, the correlation coefficient between the number of CFL bulbs used by a customer is and his/her monthly income is R = 0.362 and R^2 = 0.131 indicating positive association. Particularly, this result shows that 13.1% of the variation in the number CFL used by a customer is explained by his/her monthly income. About 87% of the variation in the number of CFL can be attributed to the supply of CFL, understanding level of the customer towards energy saving issues. However, there is a relatively smaller correlation coefficient between the total number of bulbs and monthly income of a customer which is R = 0.206 and R^2 = 0.042. This result implies that only 4.2 % of the variation in the total number of bulbs used is explained by the monthly income of a customer. These percentages clearly show that monthly income much more affects the number of CFL than the total number of bulbs used. For the maximum monthly income of Birr 8000, the probability of using CFL was not significantly affected by the level of understanding of a customer.

4.2 Recommendations

- ❖ The Ethiopian Electric Power Utility office should work in harmony with concerned government and non-government bodies to increase the proportion of users of CFL from 57% to a higher value in order to save the huge amount of energy. This can be achieved by solving all the problems mentioned above. Moreover, it is essential to modernize the input materials and upgrade the skills of field workers so as to fix the technical problems and reduce the rate of power interruptions.
- ❖ All CFL bulbs are not equally efficient in saving energy or money. To this end, customers need to consult professionals so as to select the most efficient CFL bulbs.
- ❖ The probability that a customer will use CFL bulbs is significantly affected (at 0.05% level) by the monthly income and the level of his/her understanding towards energy saving. Therefore, concerned governmental and non-governmental bodies should work in harmony to enhance the understanding level of the customers especially those with low (less than the average) monthly incomes.

Acknowledgements

We are grateful to the almighty God, the merciful and compassionate that helped us in all endeavors of our lives.

Our second deepest acknowledgement goes to WolaitaSodo University for financial support, provision of materials for the research, encouragement and timely follow up.

Our special thanks go to the Ethiopian Electric Power Utility Offices in Addis Ababa (Main Office), WolaitaSodo, Areka and Gesuba branches for providing valuable information which we used as input for the research.

We are also very thank full to Addis Ababa University College of Electrical and Computer Engineering, for allowing us to use their laboratory and for providing technical supports. Finally, we would like to thank Dawro Zone Loma WoredaGessaChere Municipality Office for encouraging and providing very important data related to EEPCO customers.

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Citation: Kassaye Bewketu *et al*. (2017). Assessment of The Use of Energy Saving Bulbs and Analysis of Their Luminous Efficiency: The Case EEPCO Customers in Wolaita and Dawro zones of SNNPR, j. of Physical and Chemical Sciences.V5I3.
DOI: 10.15297/JPCS.V5I3.03